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INDUSTRIAL WORKSHOPS AND THEIR IMPORTANCE IN RELATION TO PLACING THE HANDICAPPED*

RUFUS B. CRAIN, M.D.

In Charge of Adult Cardiac Clinic, Rochester General Hospital, Rochester, N. Y.; Member of Industrial Workshops Committee, Rochester, N. Y.

THE problem of the return to employment of its physically handicapped men and women faces every community. Not until within the last ten years has there been a crystallization of the various forces working for the betterment of this group. The World War proved a mighty stimulus to all departments of physical reconstruction. The urge to conserve man power led to constant reclassifying of men with an aim to secure the best service they were capable of rendering, whether in the field or at home. The United States was able through the experience of its European Allies and its unlimited resources to enter upon a program of physical reconstruction never before or since approached in army or in civil life. The values of occupational therapy and physiotherapy were definitely established as modalities which went hand in hand in treatment. Vocational guidance was systematically practised during convalescence.

The term rehabilitation came gradually into use and may be defined as "the rendering of a person disabled fit to engage in a remunerative occupation." The Smith-Sears Bill for rehabilitation of disabled soldiers, sailors, and marines in June, 1918, paved the way for the passage of the Fess-Kenyon Bill in June, 1920, which, while giving federal aid, laid the direct responsibility of carrying on the rehabilitation work upon the state officials (1). The development of workshops was a necessary medium for production. Practised as it was in the army, occupational therapy often converted a soldier's tent or room into a miniature workshop. Many remarkable things

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were devised and made by bed patients.

Bryant (2) in his work on "Convalescence, Historical and Practical" stresses the stages gone through by every patient after serious illness or injury. He says:

> In the earliest stage of recovery, it may at first be impossible to interest the patient in any other than the simpler or even the very simplest and most elementary forms of Handcraft occupation,—this because of the tendency of all patients, to revert, after serious illness, to a childish or even infantile type of mentality. . . . .
>
> In the second stage of recovery, during which the patient is again beginning to take some serious interest in life, the lighter occupations such as Handcraft work tend to become the avocations toward which the recovering patient looks for relief from more serious occupational work. The more serious work should usually be in the nature of Educational or Shop work which may hold some promise of being of lasting value to the patient.
>
> In the third stage of mental recovery, the lighter vocational or curative work tends to be almost entirely crowded out of the foreground, firstly in proportion to the total mentality of the patient, and secondly in proportion to the intensity of his desire to take up again the full burdens of life.

The present day conception of the sheltered shop is very well described by Moses A. Leavitt in his treatise on "Handicapped Wage Earners" (3). He classifies such shops into five distinct categories:

> 1. The therapeutic or curative workshop endeavors, through unskilled routine work processes, to physically harden the disabled person, or to build up in him work habits and a better morale.
>
> 2. The vocational training shop offers trade retraining to suitable disabled persons.
>
> 3. Permanent sheltered employment is provided by some shops for the group considered unemployable in regular industry.
>
> 4. Sheltered shops conceive it as part of their function to determine the working capacity of a disabled person, for the purpose of making vocational plans.
>
> 5. Sheltered shops have also been established to provide part-time employment for women, who, because of dependent children and the duties of maintaining a home, have only a limited time at their disposal for remunerative work.

"The usual practice of a sheltered shop," as Leavitt points out, "has been to confine itself to one or two of these specific functions, although there are workshops which have been organized to meet all the needs outlined above."

Development and Organization of Shops

The Industrial Workshops of Rochester had their inception as the "Little House" established in 1919 and later known as the Curative Workshop. Both were conducted as activities of the Tuberculosis and Health Association of Rochester and Monroe County. Occupational therapy only was given to patients. This form of treatment did very well for those who had jobs to return to. A larger group, however, could not return to their former occupations and required vocational training or careful job placement. This difficulty led to the appointment in 1924 of a subcommittee to study the problem. This committee of three, with Dr. Kirby G. Collier as chairman, gave the subject considerable study over a period of two years. Finally in October, 1926, a reorganization of the shop was effected. A new division of industrial therapy was created. This departure was stimulated in part by the success of a shop in New York City conducted under the supervision of the New York State

Bureau of Rehabilitation. This shop, the committee found, had adopted the contract plan in securing work. It maintained a factory atmosphere and had definite machinery through the State Bureau for the return of its disabled men and women to work.

We were fortunate in having as a member of this committee Mr. Leslie S. Wood, District Director of the State Bureau of Rehabilitation, who was familiar with the operation of the New York shop.

The new division in Rochester, for the sake of convenience, was called Shop B, while the division of occupational therapy, Shop A, continued to function as previously. At present a Shop Committee of six, of which Mr. Wood is chairman, controls the policies of both shops, while a larger committee, the Occupational Therapy Committee, acts as an advisory body.

The present shops are located at 14 Charlotte Street in a section of the city rapidly becoming industrial in character. The building, a two-storied frame structure, is within easy reach of street car lines and at the same time sufficiently removed from main thoroughfares to minimize parking difficulties. Shop A occupies the second floor and Shop B, the first. There is also on the first floor a room which serves as an office and a gift shop, an outlet for Shop A's products.

Both shops are under the direct supervision of Miss Elizabeth K. Wise, a young woman unusually well fitted for the difficulties of such a position. There are two trained occupational therapists who assist in Shop A and who also take turns in visiting home bound patients, and in working with patients at the County Hospital.

The cases in Shop B are under the direction of a foreman who has had a long experience in handling men. He combines the qualities of an accurate worker with the tact and patience necessary in dealing with substandard men and women.

Sources of Patients

The patients come principally from the New York State Bureau of Rehabilitation, outpatient departments of hospitals, social agencies, plant medical departments, and private physicians. Insurance carriers refer a few cases. The diagram shown in Figure 1 best illustrates these sources.

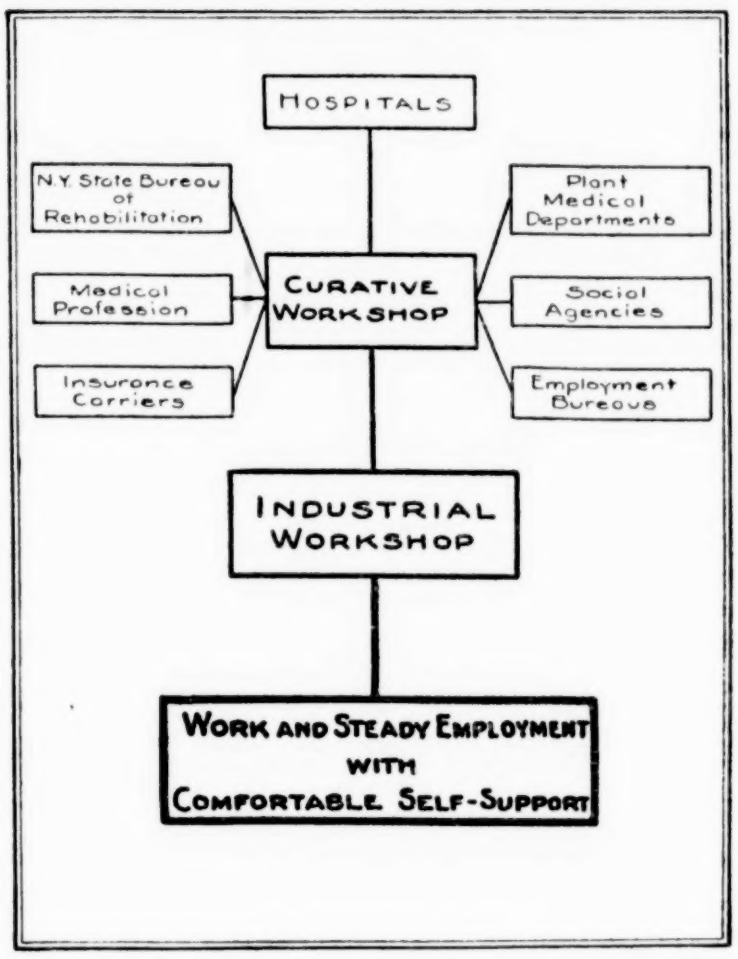

FIG. 1.—Proposed plan for returning the wage earner to comfortable self-support in industry, after sickness and accident.

The agencies referring patients are furnished with a blank for a history and physical examination to be filled in by a physician. This blank aims to cover the points considered by em-

ployers who require a physical examination of applicants for employment. A complete physical examination is a fundamental step in the successful placement of disabled persons. If this cannot be carried out, a Medical Advisory Committee, a subcommittee of the Occupational Therapy Committee, stands ready to make such examination.

A policy of the shops is to return patients to full time employment in industry. Therefore the Shop Committee has sought to encourage the sending of patients who might, through treatment and training, be restored to this group. It is hoped that at a later date provision will be made for permanent part time employment.

The patients, upon reaching the shop, are interviewed by Miss Wise and a detailed history is taken. This covers educational and work experience. The advice of the examining physician regarding work is carefully read and considered. Patients are first placed in Shop A for a general sizing up of their mental attitude and dexterity. The handicrafts are used to bring out these qualities. An effort is made to impress upon each patient that the shops are not a place for money-making but rather for *work treatment* which is to result in their return to employment.

The articles made in Shop A include baskets, toys, book ends, leather goods, rugs (woven and hooked), tables and chairs for children, fireplace screens, bird baths, etc. Chairs are caned and repaired. Many special orders for gifts are received weeks before Christmas, which is a season when extra help is called in and the staff works overtime. The proceeds from the sale of these goods are divided among the patients. The amounts are never large but may be termed pin money.

An effort is being made to find some staple article for which there is demand and the manufacture of which will not require expensive material or machinery. This would be especially valuable for the permanent part time group when provision for them is possible. Home bound and County Hospital patients are given similar kinds of work. The instructor takes the material to the patient and after a few lessons leaves him to carry on with only occasional check-ups. It is astonishing how wrapped up these patients become in their tasks. About two years ago, because of an impending limitation of our budget, it was felt necessary to discontinue the home bound service. So many appealing letters from patients affected were received, however, that the committee was able to secure additional funds for the resumption of the home visitor service.

Patients having a position to return to and needing mental stimulation and muscle training are usually kept in Shop A until the time of their discharge. Those waiting for job placement or vocational training, at present the largest group, are in a few days transferred to Shop B and are there given simple repetitive operations, mostly bench work, allowing them to be seated. Such operations as the assembling of the parts of a loud speaker for a radio, tinning and tapping telephone switchboard connecters are among those operations found useful.

Shop B has much the appearance of a section of a factory. Usually about

ten or twelve men are engaged in work. Their hours are gradually increased as advised by their physician. The labor turnover is made as rapidly as is consistent with proper preparation for full time employment.

The shop's contracts with factories specify production at 10 per cent. less than the factory is able to do the same work for. This is usually an inducement in securing work. The patients are paid a base rate of 15 cents an hour for the first two weeks and while they are learning new work. Of the money received for contract work, the patients receive about 60 per cent. and the remaining 40 per cent. is used for overhead expense. Direct labor costs are about three times as great as indirect labor costs.

The New York State Bureau of Rehabilitation is responsible for the placement of about 75 per cent. of patients ready for employment. The Bureau gives its services without charge. The remaining 25 per cent. are placed by the various social agencies or, as it not infrequently happens, find their own jobs. The friendly counsel of the State Bureau of Rehabilitation is always available to the members of this group even though it does not actually make the placement.

Types of Cases Treated

There is a great variety in the conditions encountered and each offers a special problem. The main groupings are:

1. Respiratory diseases, including cases of arrested tuberculosis.
2. Orthopedic conditions.
3. Neuroses and psychoses.
4. Postoperative cases.
5. Arthritis.
6. Industrial accidents.

Cases of epilepsy are not treated, nor are other cases which may unfavorably affect the morale of the shops.

Results in Placement

For the past two years there has been returned to full time work in industry, on an average, one patient a week. A follow-up about three months after placement is made before the State Bureau reports its cases as rehabilitated. A survey early in February, 1929, of the first fifty-six patients discharged after the reorganization of the shops in October, 1926, is of interest. A period averaging eighteen months had elapsed since these patients were returned to work.

Known to be working full time	37
Known to be working part time	2
	39

This makes a total of thirty-nine patients working, or 69 per cent. of the fifty-six treated. With regard to the remaining seventeen not reported working, the information was as follows:

Undergoing vocational training	1
Dead	2
Retired	1
Left to be married	1
Chronically ill (two returned to State Hospital)	3
Unemployed	5
Unwilling to work	1
Could not be located	3
	17

Five of the fifty-six patients, through their own efforts, had secured better jobs than those in which they were originally placed by the shops. A

TABLE 1.—CASES OF HEART DISEASE (A) RETURNED TO FULL TIME WORK IN INDUSTRY AND (B) RETURNED TO SCHOOL

CASE NO.	NAME	AGE	SEX	MARITAL STATE	DIAGNOSIS (CARDIAC)	PREVIOUS OCCUPATION	LENGTH OF WORK TREATMENT	POSITION AFTER PLACEMENT OR TRAINING
Returned to Full Time Work in Industry								
1	E. A.	34	M	M	Cardiac Neurosis; Class I	Milk peddler; driver of laundry cart	2 wks.	Driver of laundry cart.
2	C. G.	54	M	W	Hypertensive heart disease; auricular fibrillation; Class II-A	Worker in shoe factory; storekeeper	6 wks.	Cashier in department store.
3	C. H.	55	M	M	Cardiac enlargement; complete heart block; Class II-A	Shipping clerk	6 wks.	Checker in shipping department; died.
4	C. L.	33	M	S	Inactive rheumatic heart disease; mitral stenosis; Class II-A	Tree surgeon; salesman	5½ wks.	1. Course in printing at Empire School of Printing, Ithaca, N. Y. 2. Owns and edits newspaper at Genoa, N. Y.
5	H. S.	45	M	W	Inactive rheumatic heart disease; mitral insufficiency; auricular fibrillation; Class II-B	Baker; janitor work in bakery	2 mos.	1. Light carpenter work for construction company. 2. Clerk in stock room of hotel; died.
6	F. Y.	61	M	M	Myocardial insufficiency; cardiac enlargement; Class II-A	Leather goods; harness maker	4½ wks.	In charge leather goods in department store.
7	B. C.	17	F	S	Inactive rheumatic heart disease; mitral stenosis; Class II-A	Light assembly work in factory	5½ mos.	Light assembly work in a different factory.
8	W. P. M.	62	M	?	Arteriosclerotic heart disease; Class II-A	Manufacture of machinery; making wire heddles	1 mo.	Returned to same position; died.
9	J. P.	59	M	M	Inactive rheumatic heart disease; mitral insufficiency; hypertension; Class II-B	Lens grinding and polishing	2 wks.	Returned to same position.

Returned to School

1	J. B.	14	M	Active rheumatic heart disease; mitral insufficiency and stenosis; Class II-A	Schoolboy	5½ mos.
2	H. F.	10	M	Inactive rheumatic heart disease; mitral insufficiency; Class II-A	Schoolboy	3 mos.[1]

[1] Home bound patient.

Returned to school.

Returned to school.

comparison of wages where this information was available showed in the majority of cases but small differences.

Since October, 1926, thirty-six cardiac patients have been treated. The following disposition of this group was made:

Returned to full time employment	9
Returned to school	2
Unable to return to full time employment because of cardiac condition	10
Nonsusceptible to employment for other reasons	15
	36

All but three had organic heart disease and in the majority of instances the functional classification varied between II-A and II-B. Three patients returned to full time work have since died. (See Table 1.)

As pointed out by Dr. Alfred E. Cohn at the recent Annual Meeting of the American Heart Association, it is difficult to say what kind of work is best suited to cardiac patients, for an analysis of the jobs offered by many concerns is not available. The Industrial Workshops, we believe, are helping to build up a work experience in this respect. Industrial physicians with an interest in heart disease have a great opportunity in gathering statistics for the solution of this problem.

Shop Budget

The Community Chest, through the Tuberculosis and Health Association, makes an annual allowance of $6,000. This is divided as follows:

Salaries	$5,460
Rent	300
Material	200
Tools	40
Total	$6,000

This amount has been supplemented for the past two years by $800 from the Women's Educational and Industrial Union. Since April 1, 1928, the State Bureau of Rehabilitation has paid $1 a day tuition for every case it referred where shop treatment has proved of value in the rehabilitation plan. Insurance carriers are beginning to utilize the shops and it is hoped that tuition fees from this source may increase.

The money received from contracts with various industrial establishments for work done in Shop B is used for payment of one-half the overhead expense of the shops. This includes rent, light, heat, telephone, and janitor service. From this amount are also paid the wages of the foreman in Shop B and of the office clerk serving both shops. The remainder is used for the payment of the workers in Shop B for work done, usually on a piecework basis. For the fiscal year ending October 1, 1927, a total of $2,280.39 was paid in direct labor to clients of Shop B.

Cost of Rehabilitations

For the period from April 1, 1927, to March 31, 1928, the combined shops had a budget of $8,695.11. This amount furnished service to 263 patients divided as follows:

Shop A	121
Shop B	72
Home bound	50
County Hospital	20
	263

Of this number there were fifty-seven rehabilitations. The per capita cost was $33.06; the cost per rehabilitation was $152.54. The number rehabilitated constituted 21 per cent. of all patients, and 29.5 per cent. of 193 shop patients. From July 19, 1919, to March 31, 1928, the shops have expended a total of $55,258.62, giving service to 939 patients at a per capita cost of $58.84. During this period there were 147 rehabilitations.

Summary

In conclusion it may be said that the Industrial Workshops of Rochester offer to the community:

1. Through Shop A, occupational therapy for the creation of a work spirit and the retraining of muscle function in disabled cases, including home bound patients and patients in the County Hospital.

Through Shop B, industrial therapy in a factory atmosphere as a further hardening process for industrial life. The wages paid in this shop reduce to a considerable extent the amounts paid by charitable organizations for the upkeep of this group.

2. The combined shops act (*a*) as a laboratory in which may be determined the employability of disabled persons, thereby relieving industry of the burden of conducting the same experiment; (*b*) as a demonstration to industries at large that it is feasible by proper placement to continue within their own ranks many employees considered disabled and nonproductive.

3. Vocational guidance and training through the medium of the State Bureau of Rehabilitation.

Further Needs

Thus far the shops have kept within their allotted budget. This has been accomplished only by rigid economy

and in some instances by the curtailment of necessary activities. There is a need for immediate expansion if the community is to be given the service it requires.

As previously stated, there is no provision for permanent part time work. It is hoped that in the near future another division of the shop may be established for this purpose.

BIBLIOGRAPHY

1. Vocational Rehabilitation in the United States. Federal Board for Vocational Educ., Bull. No. 120, Civilian Vocational Rehabilitation Series No. 13, June, 1927.
2. Bryant, J.: Convalescence, Historical and Practical. New York, The Sturgis Fund of the Burke Foundation, 1927, p. 168.
3. Leavitt, M. A.: Handicapped Wage Earners. New York, The Jewish Social Service Assn., Inc., 1928, p. 50.

RESPIRATORY DISEASES IN A PORTLAND CEMENT PLANT*

L. R. Thompson, M.D.

Surgeon, United States Public Health Service

AND

Dean K. Brundage, A.B.

Assistant Statistician, United States Public Health Service

THE frequency or incidence rate of disabling sickness for any group of persons is affected by a variety of factors, the more important of which have to be measured and evaluated before exact conclusions are possible concerning the effect of occupation. Such factors as age, racial stock, marital status, general physical condition, individual susceptibility to certain kinds of disease, etc., need to be appraised, and the sickness rates recomputed to show what they would be without the influence of these non-occupational factors. In this way only can one obtain a clearly defined picture of the effect on health of the work or the working environment.

Factors of Different Importance

The age factor, which is so important in the sickness severity rate based on the duration of incapacitation, was found to be a relatively unimportant influence in determining the *frequency* of respiratory disability among employees of a cement company. The workers over 45 years of age were incapacitated by respiratory illness for two consecutive working days or longer at a rate which was only 11 per cent. higher than that among the men under 25 years of age, while those in the middle age group (25 to 44) had respiratory disability less often, to the extent of 9 per cent., than did those at ages 15 to 24.

Native Americans and foreign-born Italians constituted nearly 80 per cent. of the cement works' personnel (in terms of years of life under observation). Inasmuch as the respiratory incidence rate was virtually the same for each of these two race stocks, the factor of racial susceptibility to respiratory disease could be disregarded in the present study. The rate was much the same for the single as for the married men on the payroll of the company. The physical status of the individual as appraised by the examining physicians was found to be of more importance than age in the occurrence of respiratory disability. The group composed of persons who were absent once or oftener for two consecutive working days or longer on account of

* This is the second article on the results of a study of exposure to calcium dusts presented in greater detail in United States Public Health Bulletin No. 176, "The Health of Workers in Dusty Trades. I. Health of Workers in a Portland Cement Plant." The first paper appeared in This Journal, 1929, *11*, 182.

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alcoholic indulgence experienced 19 per cent. more respiratory disability than did other employees of the company.

But none of these factors affected the respiratory incidence rate as much as one which was reflected in the mere fact as to whether an employee quit or did not quit over a certain period of time. The rate among the men who left during the three years of the study exceeded by 68 per cent. the respiratory rate among those who did not leave.

Factor of Selection Resulting from Reaction to Working Environment

This unexpected result might have been due, it was first thought, to a larger proportion of persons in poor physical status among those who quit. Therefore the years of life under observation were distributed according to the physical rating of the workers. But the percentage in each physical status was very nearly the same in either group. The general physical condition of the men appeared to be no different among those who quit than among those who stayed.

What, then, accounted for the wide difference in the respiratory sickness experience of these two groups of cement workers? The analysis was pursued in greater detail in the hope that it would throw light on this interesting question. The two groups of employees were first subdivided according to the duration of their employment in the Portland cement industry, and the respiratory frequency rates were computed for these subgroups. The results are given in Table 1 and Figure 1.

The respiratory rates by length of service among those who stayed are illuminating. In this group the frequency of respiratory disability was remarkably low among those in the industry less than two years and from two to four years. The rate was even lower among those who had spent from four to eight years in cement making, but after about the eighth year in the industry, respiratory disability occurred much oftener, mounting from a rate of 235 cases per year per 1,000 men who had had four to eight years' employment in the industry to a rate of 605 cases annually per 1,000 men with more than eight years' service.[1]

Among those who left during the period of observation, the highest respiratory disability rates occurred in the groups with less than two years and with two to four years of service. After the fourth year respiratory disabilities tended to decrease in frequency among the men who quit, though the rate remained high until the data became too meager for further observation. It is apparent from the graph (Fig. 1) that among employees of less than eight years' service the respiratory rate was about twice as high in the group which quit during the study as in the group which did not quit. Yet, as stated above, the general physical condition of the men in the two groups was rated practically the same by our own examining physicians. Could the difference be due to a greater susceptibility to respiratory

[1] This rapidly mounting curve was based on a rather small exposure, but further analysis of the data indicated that the high respiratory rate among the men with the longer service probably was not due merely to chance. (See discussion of this point in Public Health Bulletin No. 176, pp. 73-74.)

disease in the one group than in the other—a difference which would not be revealed ordinarily in a general physical examination?

TABLE 1.—RESPIRATORY INCIDENCE RATES ACCORDING TO LENGTH OF SERVICE IN THE CEMENT INDUSTRY AMONG THOSE WHO QUIT AS COMPARED WITH THOSE WHO DID NOT QUIT DURING THE PERIOD OF THE STUDY[1]

LENGTH OF SERVICE IN CEMENT INDUSTRY	ANNUAL NO. OF RESPIRATORY CASES PER 1,000 MEN AMONG		NO. OF RESPIRATORY CASES AMONG		NO. OF YRS. OF LIFE UNDER OBSERVATION AMONG	
	Those Who Quit[2]	Those Who Did Not Quit[2]	Those Who Quit[2]	Those Who Did Not Quit[2]	Those Who Quit[2]	Those Who Did Not Quit[2]
All lengths	563	336	171	154	304	459
Less than 8 yrs.	571	276	148	104	259	377
8 yrs. or longer	455	605	15	49	33	81
Less than 2 yrs.	576	282	87	48	151	170
2 to 4 yrs.	583	303	35	33	60	109
4 to 8 yrs.	542	235	26	23	48	98
8 yrs. or longer	455	605	15	49	33	81
Unknown	...	...	8	1	12	1

[1] Only those cases were included which caused absence for two consecutive working days or longer.

[2] During the period of the study, Feb. 6, 1922, to Feb. 1, 1925.

An answer to this question was afforded by the data at hand. The men who experienced no respiratory sickness which caused inability to work for two consecutive days or longer while they were on the payroll of the company during the period of the study were left out of consideration, and the frequency of respiratory attacks was ascertained for those who were disabled for more than one day by this type of illness during the three years of the investigation. Among the men who had been in the industry less than eight years, the group which quit averaged 1.203 respiratory attacks annually per person (year of life)[2] compared with only 0.591 respiratory attacks per person per year in the group which did not quit during the study. This difference in the number of respiratory attacks per person was found to account for the greater frequency of respiratory sickness in the group which quit. In other words, the larger number of respiratory cases

[2] Inasmuch as some men were on the payroll continuously during the three years, while others were employed for varying portions of this period, the unit taken was not the number of different men, but the number of years of life under observation, obtained by summing the number of days during which each employee was on the payroll within the period Feb. 6, 1922, to Feb. 1, 1925, and dividing the total number of days by 365 to obtain the equivalent number of persons under study for one full year.

per person experiencing this type of illness accounted for all or nearly all the excess in the respiratory incidence rate of the group which left the industry as compared with the group which stayed.[3]

The comparative absence of respiratory susceptibility among those who tended to remain in the industry is indicative of a process of self-selection of workers on the basis of physical suitability for the work and the working environment. Those who tended to stay on were, apparently, better adapted physically for the conditions of work than those who shifted to some

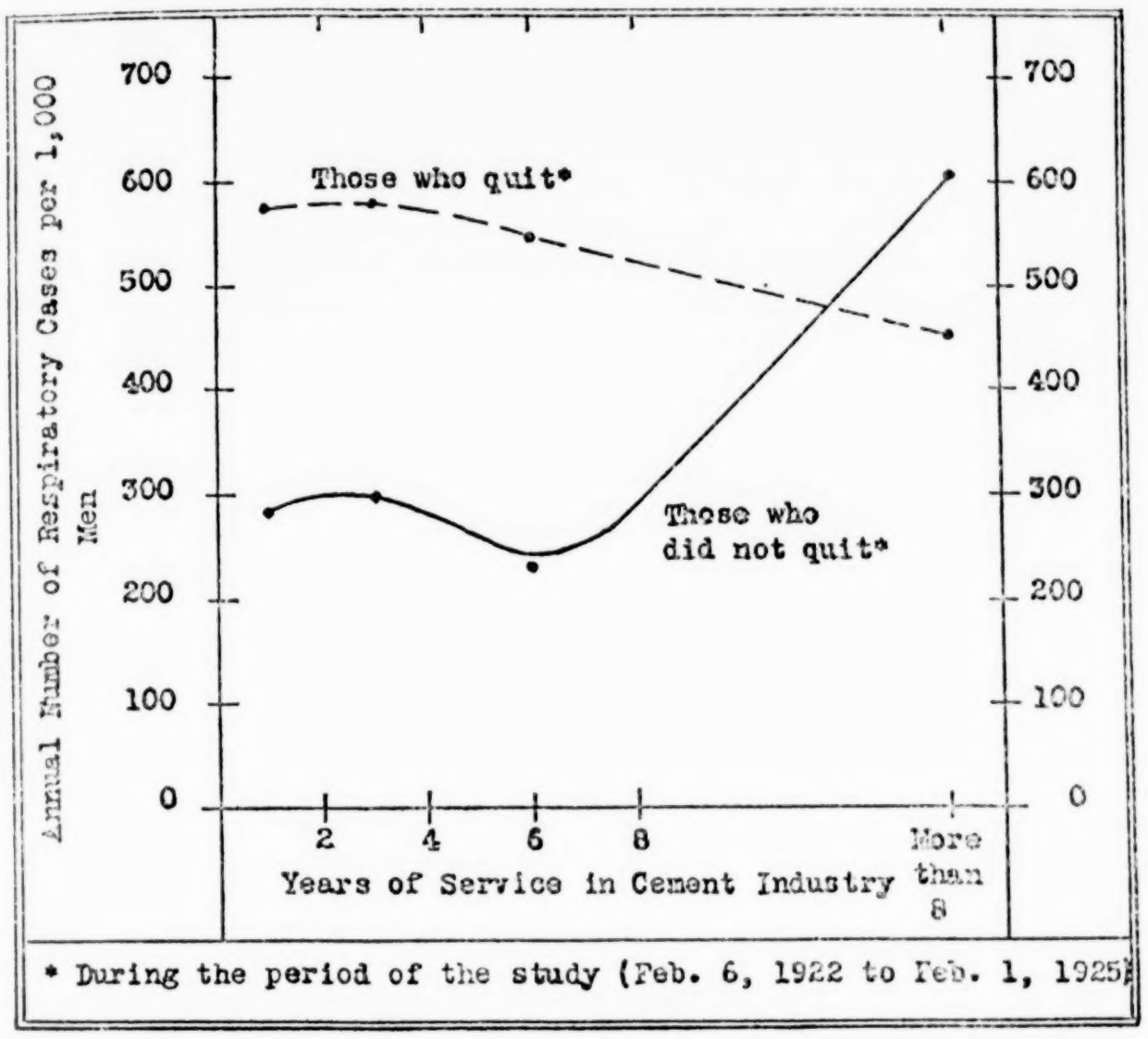

FIG. 1.—Respiratory incidence rates according to length of service in the cement industry among those who quit as compared with those who did not quit during the period of the study (Feb. 6, 1922, to Feb. 1, 1925).

among those who stayed in the industry during the period of the study, and, on this basis, it appears that about 74 per cent. of the excess disability in the group which quit was due to the factor of susceptibility. This result, however, appears to be an understatement, inasmuch as persons who remained under observation for as along as one to three years in the specified length of service groups would tend to be selected individuals with regard to their ability to tolerate dust.

[3] Computation showed that all the excess was accounted for, but some error may arise from the fact that persons under observation only a few months and having one case each would show a higher annual rate of respiratory cases per person disabled than men having one case each but who were under observation for two to three years. As a check on the results, the frequency of respiratory attacks per person experiencing such illness was ascertained only for persons carried in the morbidity record one full year in the group having less than two years' service and for those under observation for two to three years among persons who had been in the industry for two to eight years. This sort of rate for those who quit was compared with the same sort of rate

other industry. It appears, also, that the group which quit did not have a larger proportion of physical weaklings, but merely a relatively larger number of persons who were more susceptible to the specific diseases to which the given working conditions might predispose or which they might aggravate. It is more than probable that such a process of selection of workers as is suggested by the data occurs also in industries other than cement making.

It will be observed in Table 1 that the respiratory rates were more nearly of the same magnitude in the "quit" as in the "did not quit" group for those with eight or more years' service. This is quite in accordance with what would be expected, since persons who kept on working in cement dust for eight or more years would naturally constitute a selected group from the standpoint of dust tolerance. For this reason it appears that the effect of the dust is best measured by comput-

TABLE 2.—NUMBER AND PER CENT. OF TOTAL YEARS OF LIFE UNDER OBSERVATION AMONG MEN WHO EXPERIENCED ONE OR MORE THAN ONE RESPIRATORY DISABILITY[1] DURING THE PERIOD OF THE STUDY, AND THE FREQUENCY OF CASES[1] AMONG THOSE THUS DISABLED, BY LENGTH OF SERVICE IN THE CEMENT INDUSTRY, FOR EMPLOYEES WHO QUIT AS COMPARED WITH THOSE WHO DID NOT QUIT DURING THE PERIOD OF OBSERVATION

LENGTH OF SERVICE IN CEMENT INDUSTRY	YRS. OF LIFE UNDER OBSERVATION			RESPIRATORY CASES[1]		
	Total	Among Men Disabled Once or More by Respiratory Sickness[1]	Per Cent. Disabled by Respiratory Sickness	No.[1]	Annual No. per 1,000 Men Disabled	Ratio to Rate for Men with Less than 2 Yrs.' Service
Less than 8 yrs.:						
Those who quit	259	123	48	148	1,203	...
Those who did not quit	377	176	47	104	591	...
Those who quit:						
Less than 2 yrs.	151	59	39	87	1,475	100
2 to 4 yrs.	60	35	58	35	1,000	68
4 to 8 yrs.	48	29	60	26	897	61
Those who did not quit:						
Less than 2 yrs.	170	67	39	48	716	100
2 to 4 yrs.	109	61	56	33	541	76
4 to 8 yrs.	98	48	49	23	479	67
8 to 12 yrs.	55	37	67	29	784	109
More than 12 yrs.	26	23	89	20	870	122

[1] Causing absence for two consecutive working days or longer.

ing the respiratory rate for all men in the study who had been in the industry for eight years or longer in comparison with the respiratory rate of the non-quitters having less than eight years' service. The dividing line was placed at the eighth year because at or about this point the frequency of respiratory disability began to increase perceptibly among those who stayed in the industry. The men who had worked in cement dust for eight years or longer experienced more than twice as many disabling cases of respiratory illness per 100 or per 1,000 persons as the group having less than eight years' service. Not only did a larger *percentage* of these seasoned workers have one or more than one respiratory disability the longer they stayed in the industry, but the persons who suffered such disabilities experienced more frequent attacks of them. That this tendency was not simply a reflection of the age of the individuals who had given the longer service was shown by the fact that the trend was practically the same for the men under 45 years of

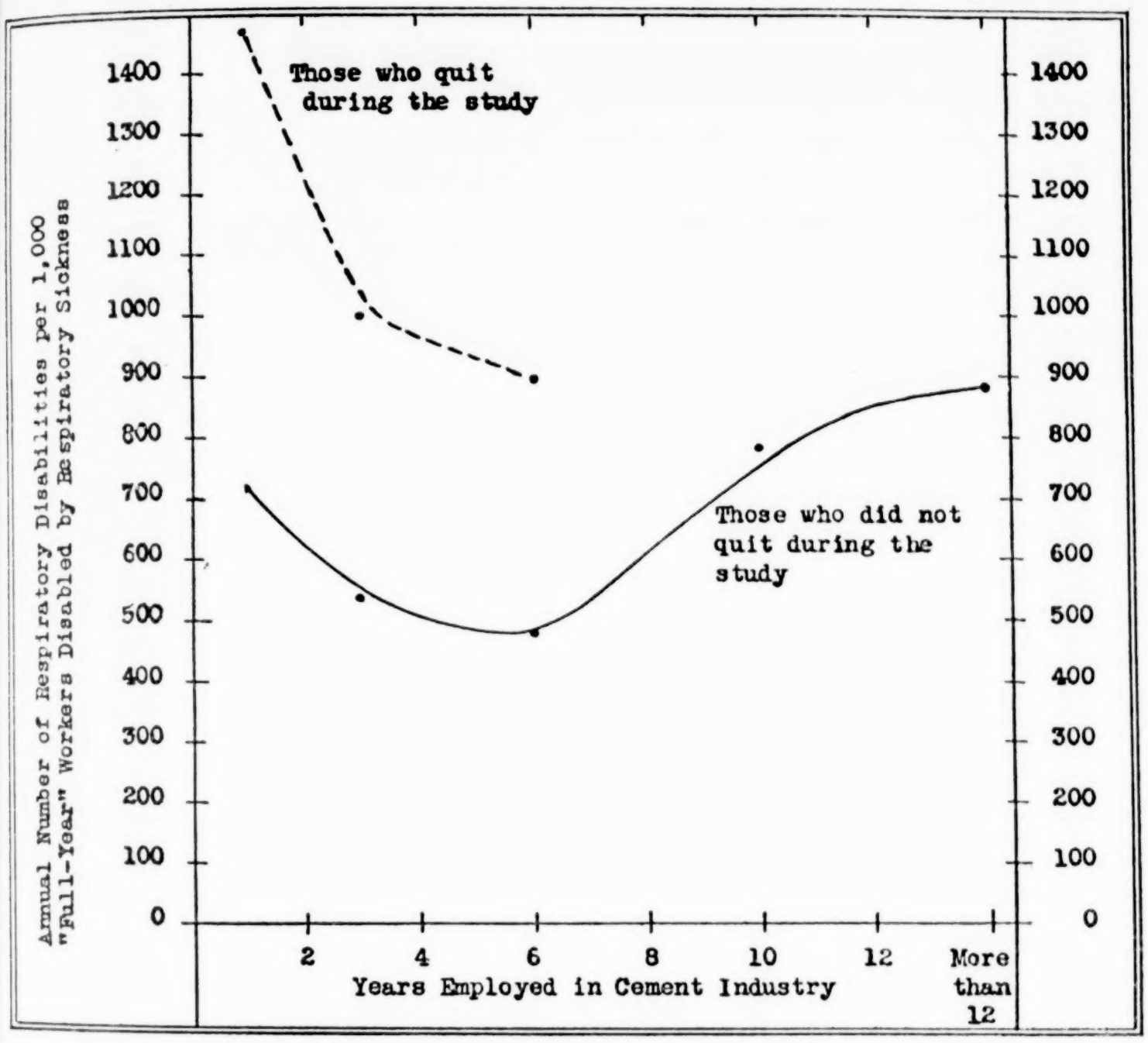

FIG. 2.—Frequency of respiratory disability among employees disabled once or oftener by respiratory disease during the period of observation (Feb. 6, 1922, to Feb. 1, 1925), by length of service in the cement industry.

age as for those above this age. It is difficult to escape the conclusion that exposure to large quantities of calcium dust, especially amounts ranging from 50 to 100 million particles per cubic foot of air, tends to predispose men to certain diseases of the respiratory system after seven or eight years of work in such an environment. The respiratory diseases which caused disability most frequently among persons of longer service in the industry were infections of the nasal mucosa and bronchi, and a predisposition to influenza or grip was indicated. Long-continued exposure to the calcium dusts appeared not to predispose to pneumonia or to pulmonary tuberculosis.

In both the relatively susceptible and the relatively immune groups, decreases occurred in the number of respiratory attacks per person after about two years' employment in the industry and up to about the sixth or the seventh year of service. The respiratory incidence rates also tended to decline during these periods of service as is shown in Table 1 and Figure 1. As indicated in the last column of Table 2, the frequency of respiratory attacks per person disabled declined somewhat more sharply in the group which quit so as to suggest that the persons most susceptible to respiratory disease tended to relinquish their jobs within two years, leaving a group which was not quite so much affected by the dust.

Process of Accommodation

A certain physical ability to become temporarily adjusted to environment is indicated by the decrease in the respiratory frequency rate from about the second to the sixth or seventh year of service, and particularly in the number of respiratory attacks per person experiencing respiratory disability. In the more permanent group of workers this decrease could not have been due to a weeding out of the susceptibles, since no one in this group left the industry during the period of observation.

Respiratory Disability According to Nature of Working Environment

Although cement dust permeated virtually all departments of the mill, there were other dusts and other factors in the working environment, the reaction to which in terms of disabling sickness could be observed with reference to the selective process described above.

In the initial stages of manufacturing the principal dust came from limestone, which was found to contain about 6.5 per cent. of free silica in the form of quartz as compared with 1 per cent. in the finished product, cement. Other dusts to which, however, only a few persons were exposed are gypsum and bituminous coal dusts. In the open quarry, work is usually carried on without regard to the state of the weather. In the kiln room very high temperatures are encountered. Employees of the mechanical department may be shifted from one part of the plant to another to carry on repair work under widely different conditions of heat, cold, dust, or dampness. For the purpose of studying the reaction in terms of respiratory disability to each of these conditions, employees were classified according to the nature of the conditions under which they worked,

even though the number of persons in several of the groups was very small.

Employees of the office, storeroom, laboratory, power and electrical departments, and yard workers other than laborers were regarded as being exposed to comparatively little dust. The yard laborers were placed in a separate category on account of the nature of their work and because their occupation constituted the vestibule to the plant, the new employees usually being given a probationary period in this work. The sickness rate for such a group would, therefore, probably reflect the reaction to work that is of a rather heavy nature, as well as the poor physical condition frequently found among casual workers in the least skilled and therefore least remunerative jobs. For these reasons the yard laborers were not included in the group exposed to relatively little dust, although the dust concentration in the yard was comparatively light except on windy days.

Employees exposed to heavier dust concentrations were grouped as follows:

Exposed principally to cement dust:
  All finishing and bag room workers.
  All employees of packing department.
Exposed principally to limestone dust:
  All employees in crusher houses, stone house, and raw mill.
Exposed to gypsum dust:
  Gypsum shovelers and scale men (finishing department).
Exposed to bituminous coal dust:
  All employees in coal house.

Other types of exposure in which comparatively little dust was involved were as follows:

Sudden changes in nature of working conditions incident to emergency and general repair work:
  All employees of mechanical department.
High temperatures:
  All kiln room workers except flue gas samplers.
Outdoor work in all kinds of weather:
  All unsheltered employees of quarry.

Table 3 shows that the respiratory rates of the employees in the dustier departments of the plant and of those exposed to the other working conditions mentioned were all considerably higher than the rate among the men working in comparatively little dust. The small number of persons, however, in at least three of the groups—*i.e.*, those exposed to gypsum, bituminous coal dust, and the heat of the kilns—renders impossible any definite conclusions concerning the effect of these conditions on the health of those exposed to them. Considering the larger groups, one finds that the dustier working places, outdoor work in all kinds of weather, and exposure to sudden changes in working conditions were associated with much higher respiratory disability rates than were shown for the group relatively unexposed to any of these conditions.

The respiratory rates according to nature of the exposure indicated wide differences in the sickness experience of relatively unselected workers as compared with the seasoned or selected group. The differences are most easily seen by referring to the last column in Table 3. Omitting from consideration the smallest groups—*i.e.*, those exposed to gypsum, bituminous coal dust, and kiln room heat—one finds that the greatest differences in the frequency of respiratory disability among those who quit as compared with those who stayed occurred in yard labor, pack-

ing, the mechanical department, and quarry labor. In general, in these departments the heavier work of a cement mill is performed; the results therefore probably represent the reaction to heavy work as well as to dustiness and the other conditions mentioned. In these four departments especially, the need is manifested for selecting and placing workers with more regard to their susceptibility to the effects of dust or other conditions involved. The employee apparently attempts to find work and working

TABLE 3.—FREQUENCY OF DISABILITY[1] FROM RESPIRATORY DISEASE, ACCORDING TO NATURE OF EXPOSURE IN A CEMENT MANUFACTURING ESTABLISHMENT

EMPLOYEE GROUPS EXPOSED TO	NO. OF YRS. OF LIFE UNDER OBSERVATION	NO. OF RESPIRATORY CASES[1]	ANNUAL NO. OF RESPIRATORY CASES PER 1,000 MEN	RATIO TO RATE AMONG THOSE EXPOSED TO RELATIVELY LITTLE DUST[2]	ANNUAL NO. OF RESPIRATORY CASES PER 1,000 MEN AMONG		RATIO OF RESPIRATORY RATE FOR THOSE WHO QUIT TO RATE FOR THOSE WHO DID NOT QUIT
					Those Who Quit[3]	Those Who Did Not Quit[3]	
All employees of cement company	763	325	426	160	563	336	168
Comparatively little dust[4]	116	31	267	100	361	225	160
Heavier concentrations of dust	323	140	433	162	514	373	138
a. Cement dust	173	83	480	180	619	348	178
1. Finishing and bag depts.	104	52	500	187	638	386	165
2. Packing dept.	69	31	449	168	595	281	212
b. Limestone dust[5]	106	36	340	127	237	391	61
c. Gypsum dust[6]	22	11	500	187	500	500	100
d. Bituminous coal dust[7]	22	10	454	170	750	308	244
Quarry labor[8]	95	53	558	209	813	429	190
Yard labor[9]	107	47	439	164	633	191	331
Sudden changes (mechanical dept.)	89	38	427	160	682	343	199
Heat in kiln room[10]	33	16	485	182	500	471	106

[1] Causing absence for two consecutive working days or longer.

[2] Rate among men exposed to relatively little dust = 100.

[3] During the period of the study, Feb. 6, 1922, to Feb. 1, 1925.

[4] Employees of the office, storeroom, laboratory, power and electrical departments, and yard(except yard laborers).

[5] Employees of the crusher house,stone house, and raw mill.

[6] Gypsum shovelers and scale men (finishing department).

[7] Coal house workers and flue gas samplers.

[8] Exclusive of quarry workers who are sheltered from the weather.

[9] Yard laborers only.

[10] All kiln room workers except flue gas samplers.

conditions for which he is physically well adapted, but he does it by the wasteful trial and error method. The factory employment department might prevent needless labor turnover by developing physical examinations which would indicate the extent of tolerance fashion, and it affords the hope of development into an effective means of preventing industrial morbidity. The possibility that the spirometer might be of some use in selecting workers for certain working conditions was mentioned in the first paper.

TABLE 4.—FREQUENCY OF DISABILITY FROM RESPIRATORY DISEASES (ADJUSTED FOR PHYSICAL STATUS) AMONG THOSE WHO DID NOT QUIT DURING THE STUDY, BY NATURE OF EXPOSURE IN A CEMENT PLANT

EMPLOYEE GROUPS[1] EXPOSED TO	NO. OF YRS. OF LIFE UNDER OBSERVATION	NO. OF RESPIRATORY CASES[2]	PER CENT. OF TOTAL YRS. OF LIFE IN PHYSICAL RATINGS 3 AND 4	ANNUAL NO. OF RESPIRATORY CASES PER 1,000 MEN (ADJUSTED FOR PHYSICAL STATUS)[3]
All employees of cement company....	459	154	17	302
Comparatively little dust.....	80	18	10	234
Heavier concentrations of dust.....	185	69	16	376
a. Cement dust.....	89	31	12	356
1. Finishing and bag depts.....	57	22	14	390
2. Packing dept.....	32	9	8	294
b. Limestone dust.....	69	27	17	386
c. Gypsum dust.....	14	7	18	512
d. Bituminous coal dust.....	13	4	36	304
Quarry labor.....	63	27	8	437
Yard labor.....	47	9	31	178
Sudden changes (mechanical dept.)...	67	23	21	335
Heat in kiln room.....	17	8	42	446

[1] Departments and occupations included in each group are shown in footnotes 4 to 10 of Table 3.

[2] Causing absence for two consecutive working days or longer.

[3] The adjusted rates show what the frequency of respiratory diseases would be if the distribution of the staying workers according to physical condition were the same in each exposure group as among all employees of the plant as a whole. In this way is eliminated the effect of an unequal distribution in the different kinds of working environment of persons in poor physical condition.

to different kinds of exposure to which applicants for work might be subjected in the course of duty, and by placing them with regard to the information thus obtained concerning their physical idiosyncrasies. Such a procedure would aid the worker in what he attempts to do anyway in rather blind

Of particular interest are the sickness rates according to type of exposure of those who stayed in the industry, because such rates appear to reflect the effect of work and working conditions on the health of a favorably selected group. Not even those who did not quit in the several exposure

groups, however, are strictly comparable from a physical standpoint because the intensity of the selective process must depend to a considerable extent on the requirements of the different occupations. For example, few men in poor physical condition could carry on indefinitely in cement packing, although they might be able to work for a long time in the less arduous occupations of the coal house or kiln room. It appeared necessary, therefore, to ascertain what proportion of the population, in terms of the years of life under observation, in each type of working environment were in poor physical condition or were regarded as being so by the examining physician when he rated men in class 3 or 4. Among those who did not quit, the groups which showed the smallest proportion in poor physical condition were the men in the packing department and those in the quarry, only 8 per cent. of the years of life in each of these departments falling in class 3 or 4. On the other hand, 42 per cent. of those who did not quit in the kiln room and 36 per cent. in the coal house were given low physical ratings. In order to eliminate the effect of these wide differences in physical status, the respiratory incidence rates were recomputed in Table 4 to show what the rate for each group would be if the distribution according to physical condition of the staying workers were the same under each type of working environment as among all employees of the plant as a whole. With the rates thus adjusted, the effect on the respiratory system of each of these several different kinds of exposure in the plant is seen more clearly.

The largest number of disabilities from respiratory diseases according to the adjusted rates occurred among those exposed to gypsum dust and to the heat of the kilns; but, as was previously pointed out, these groups were not large enough to afford significant sickness rates. The adjusted respiratory rates for the larger groups shown in Table 4 indicated that the relative importance of the several different types of exposure was as follows:

1. Exposure to all sorts of weather (work continued during storms, etc.).
2. Exposure to heavy concentrations of limestone dust.
3. Exposure to heavy concentrations of cement dust.
4. Exposure to sudden changes in working conditions.

The lowest adjusted respiratory rates among the "selected" workers were for the yard laborers and the group exposed to relatively little dust. The yard laborers generally work out of doors, but ordinarily do not keep at their jobs in the open during storms and the severest weather as do the quarry workers. The exceptionally low adjusted respiratory rate of 178 cases a year per 1,000 "selected" yard laborers indicates the healthfulness of fairly heavy work out of doors among persons well adapted physically for this type of labor. The next to the lowest adjusted respiratory rate (234 cases a year per 1,000 men) occurred among the group relatively unexposed to any untoward working condition—namely, employees of the office, storeroom, laboratory, power and electrical departments.

Summary

The more important factors affecting the frequency of disabling attacks of respiratory disease among employees of a cement company were measured and evaluated before conclusions were drawn concerning the effect of working conditions. None of the factors measured affected the respiratory incidence rate as much as one which was reflected in the contrast between the respiratory rate among those who quit and the rate among those who did not quit during the three years of the study. A rather detailed analysis revealed indications of a process of self-elimination from the industry of those who were more susceptible to respiratory illness and who were affected deleteriously by the dust.

The effect on the respiratory system of exposure to different kinds of working conditions was observed by means of respiratory disability rates adjusted for differences in the physical condition of persons employed in each type of environment among men who tended to remain in the industry. Persons obliged to continue work in the open during all kinds of weather showed the highest disability rate from respiratory illness, and were followed by the group exposed to the heavier concentrations of dust. Men exposed to limestone dust experienced slightly more respiratory disability than those working in cement dust. The respiratory rate also was high in the emergency and general repair crews which were often subjected to very sudden changes in the nature of their working environment.

CALIBRATION OF THE KATA-THERMOMETER OVER A WIDE RANGE OF AIR CONDITIONS*

C. P. YAGLOU AND KROUM DOKOFF

Department of Ventilation and Illumination,
Harvard School of Public Health, Boston, Mass.

THE cooling laws of the kata-thermometer have been studied by many workers, but the range and combinations of the air conditions covered were limited. On account of these limitations, the kata formulas do not quite agree and are not accurate enough for general ventilation work.

To our knowledge, the kata has not heretofore been calibrated for temperatures over 100°F., it being generally assumed that the formulas applying in temperatures below 95°F.—*i.e.*, when the kata cools from 100° to 95°F.—would hold also for temperatures exceeding 100°F.—*i.e.*, when the kata warms from 95° to 100°F.

The present work was carried out for the purpose of calibrating the instrument over a wide range of accurately controlled air conditions, so that it could be used satisfactorily for high or low temperatures and humidities, and for any air velocity between 0 and 650 feet per minute.

METHODS

The observations were made in the psychrometric chamber of the Harvard School of Public Health (1). Work was begun in November, 1927, and continued until June, 1929, so that the usual variations in barometric pressure which occur in our climate might be taken into account.

Kata Factors

Two dry kata-thermometers had to be used because one of them broke in the first part of the study. The factors of these instruments were 463 and 452, respectively. The factor of the single wet kata used was 452. All three factors were checked by a method similar to that used by the maker (2, p. 17). For air temperatures between 63° and 71°F., the difference between the maker's factors for the three instruments and those found by us was not significant.

Production and Measurement of Air Velocity

For velocities between 0 and 100 feet per minute we used the whirling arm method. The kata was attached to one end of a thin metal arm $4\frac{1}{2}$ inches from the center line of a rotating vertical pillar, and the thermometer to the other end at an equal radius. The speed was controlled by varying the resistance in series with the motor

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armature. Approximate corrections for the "swirl" were secured by a method similar to that used by Hargood-Ash and Hill (2, p. 22). They averaged about 8 per cent. of the apparent velocity. The air velocities covered by the whirling arm method were fixed at 20, 40, 75, and 100 feet per minute.

Velocities of 220, 440, and 660 feet per minute were produced by means of a variable speed multivane blower, and measured with a 4-inch Tycos anemometer. The anemometer was calibrated against a miniature double pitot tube which had, instead of the usual static tube, an aspirating tube facing downstream. The pressure difference between the two tubes was 75 per cent. greater than that of a standard pitot-static tube. These pressures were measured by means of a Wahlen gauge (3), which in our work was sensitive to pressures of about 0.0002 inch of water.

The blower was arranged to produce horizontal air currents across the room, at a level of about $3\frac{1}{2}$ feet from the floor. Four thicknesses of fine mesh wire screen were attached to the blower outlet in order to reduce the initial air velocity and to produce more uniform flow. The desired air velocities around the kata bulb were obtained by placing the kata stand at different distances from the blower outlet along the axis of the stream, and by controlling the blower speed.

The practicability of this method is shown in Figure 1, which gives the velocity distribution along and across the air stream, as determined by the double pitot tube. It will be seen that, while the velocity along the air stream decreases progressively as the distance from the blower outlet increases, the traverse velocity remains quite uniform over the cross-sectional area occupied by either the kata or the anemometer. This, at least, was the case so long as we kept $5\frac{1}{2}$ feet away from the blower.

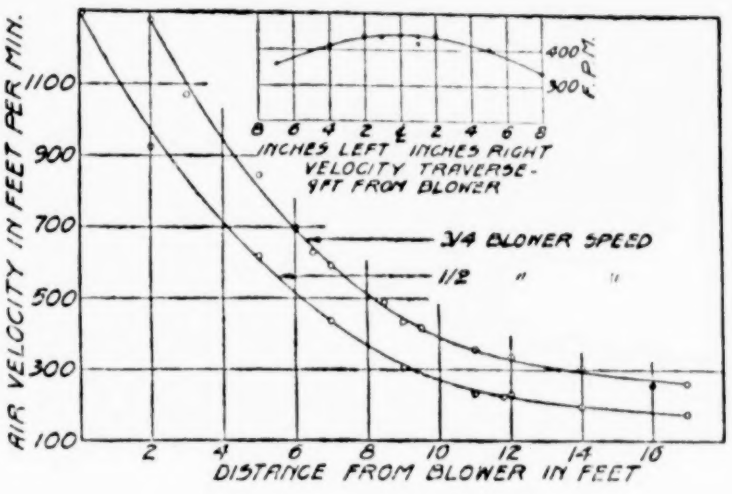

FIG. 1.—Velocity distribution along and across air stream.

The minimum distance at which kata observations were made was 7 feet from the blower, and this, with nearly full blower speed (allowing sufficient margin for adjustments), corresponded to our maximum velocity of 660 feet per minute. For a velocity of 440 feet per minute the blower speed was reduced to about three-quarters of the full speed, and the distance from the blower was increased to 9 feet. For a velocity of 220 feet per minute the speed was half the full speed, and the distance 12 feet. These were also the conditions under which the anemometer was calibrated, its actual readings being 600, 400, and 200 feet, respectively.

The advantage of this method over the usual wind tunnel method is that it approximates more nearly the conditions under which the kata-thermometer is used in practice. It is probable that the ordinary wind tun-

nels, on account of their limited size, may appreciably affect heat exchange by radiation and convection between kata and environment.

temperature and humidity for the room surfaces to reach thermal equilibrium with the air. The ventilating fans were then stopped and all dampers

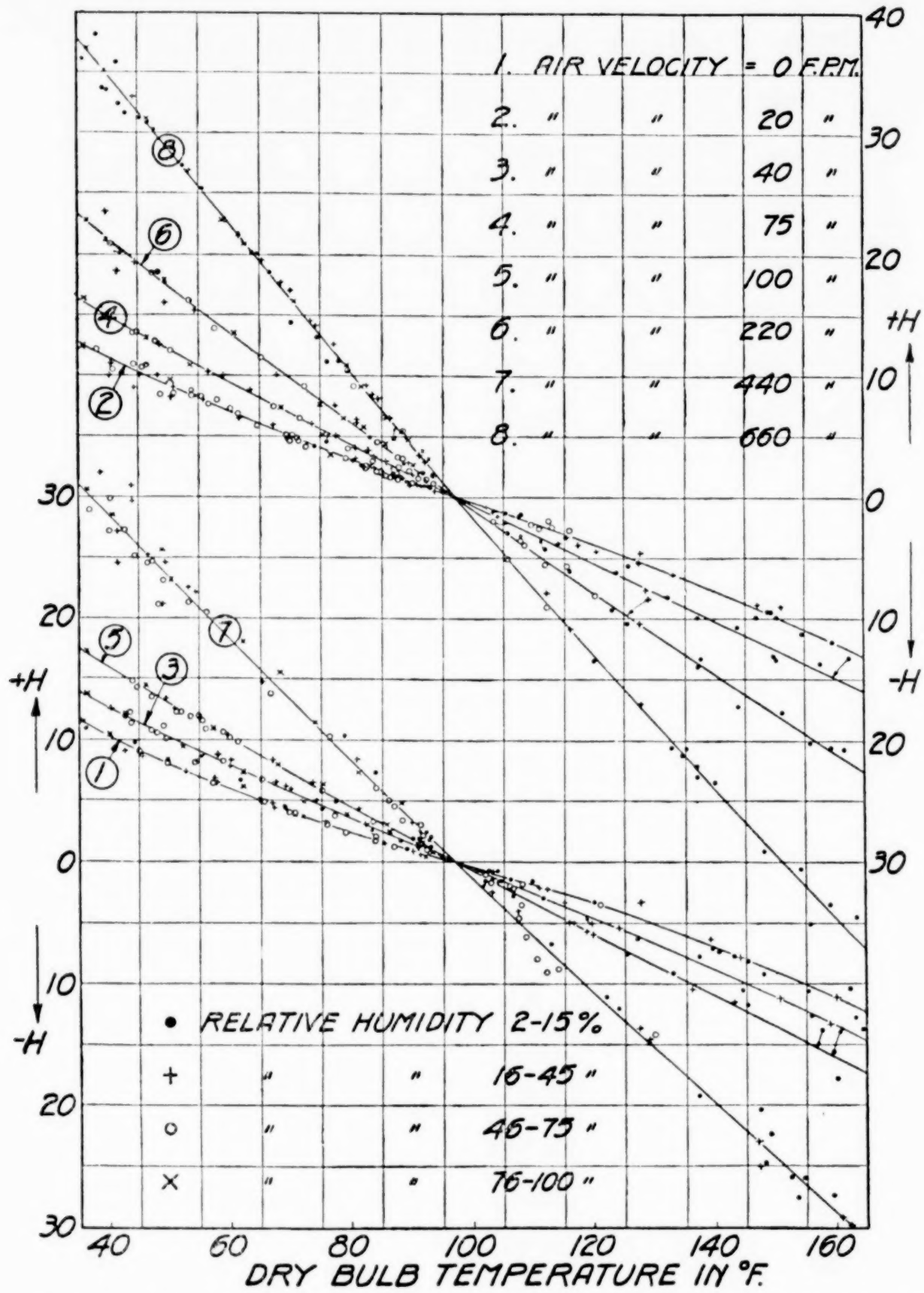

FIG. 2.—Dry kata cooling and warming powers (±H) in relation to dry bulb temperature and air movement.

Experimental Procedure

Before each set of kata readings was made, the air conditioning apparatus was run long enough at the desired

shut tight. After the air currents in the room had subsided, the desired air velocity was produced, and finally the kata observations were made.

Since the room is well insulated and practically air tight, the air conditions changed but little during the period of observation. In experiments with air velocities of 220, 440, and 660 feet per minute, it was found that turning the ventilating fans on at low speeds did not affect the kata readings. The number of consecutive kata observations for any given air condition varied from two to eight, depending on their agreement. The first reading was usually discarded; sometimes the second and third also had to be discarded. The remaining readings were averaged.

We measured dry and wet bulb temperatures before and after each set of kata observations, by means of a sling psychrometer in the first half of the study, and by means of an aspirating psychrometer in the latter half. In addition we recorded, before and after each kata reading, the dry and wet bulb temperature of the air at kata level and 9 inches from the kata, with thermometers exposed to approximately the same air currents as the kata itself.

Measurements of air velocity were likewise made before and after each set of kata observations. Whenever the second value differed considerably from the intended velocity, the entire set of readings was discarded.

The approximate range of dry bulb temperatures covered with each of the given velocities was 35° to 165°F., the approximate range of wet bulb temperatures, 32° to 112°F. At first the kata readings were taken at definite relative humidities, *viz.*, 10, 30, 60, and 95 per cent. Later it was found that such close control was superfluous, and the humidity ranges specified in Figures 2 and 4 were therefore adopted. Altogether, 2,762 kata observations were made: 1,387 with the dry kata, and 1,375 with the wet kata. The figures and tables given in this paper have been constructed from average values.

Data and Discussion of Results

Dry Kata

Cooling and Warming Power in Relation to Dry Bulb Temperature and Air Movement.—In Figure 2, the dry kata cooling and warming powers ($\pm H$ in millicalories per second per square centimeter of kata bulb) are plotted against dry bulb temperatures for constant air velocities. The curves were drawn empirically through the averages of the observed values. They do not cross the temperature axis at 97.7°F. (36.5°C.), which in all formulas is taken as the mean cooling temperature of the kata, but they all converge close to 97°F. This temperature was established quite accurately from plots on scales larger than those of Figure 2. It also agrees very well with mathematical computations of the mean kata temperature in air at 94°F.

In contrast to assumptions by Hill (2, pp. 17 and 24; 4, p. 399) and Weiss (5, p. 11), the relationship in Figure 2 is not linear, for the plots exhibit well-defined curvatures of varying degrees, depending on the temperature and the velocity of the air. The temperature effect, which is most noticeable in the still air curve, has already been identified by Angus (6, p. 25) and Vernon (7, pp. 20–22), who attribute it, in whole or in part, to the natural convection currents of air which are set

up by the kata itself. These workers believe that on account of these convection currents the kata factor varies with the temperature. In our opinion, the kata factor cannot vary; it is the coefficient of heat transmission—heat transmission per unit of time, per degree of difference in temperature between the mean kata temperature and air—which varies. For still air, this coefficient was fixed by Griffith (6, p. 21) at 0.27 in his empirical formula

$$H = \frac{F}{T} = 0.27\ \theta^{1}$$

and was assumed to remain constant regardless of temperature. According to our still air curve (Fig. 2) the coefficient varies from about 0.32 at 35°F. to 0.21 at 90°F., reaching Griffith's value of 0.27 at 68°F. The order of variation is reversed for temperatures exceeding 100°F.

Air movement at right angles to the kata bulb tends to diminish the influence of the natural convection currents by blowing them aside. Probably for this reason the extremities of the graphs in Figure 2 tend to straighten out as the velocity increases. An approximate estimate of the air velocity at which the influence of these convection currents ceases was secured by noting the velocity required to blow off in a horizontal direction the visible supersaturated water vapor rising from the bulb of the wet kata in low air temperatures. In air at 35°F., the velocity required to do this was about 160 feet per minute. In higher temperatures the little clouds of water vapor became less and less visible, and the course of the currents could not be ascertained.

In addition to the influence of the natural convection currents, variations in air density due to temperature seem to affect appreciably the cooling and the warming power of the kata. In Figure 2 this is indicated by the fact that the curves are not symmetrical to the temperature axis, and that for any given value of θ the warming power is always lower than the cooling power. It is evident, therefore, that the factor of air density is responsible in whole or in part for the concave curvature of the high velocity plots. This density effect varies with θ and with the air velocity. As an average for our entire range of θ values, the warming power is about 4 per cent. lower than the cooling power in still air, and 7.5 per cent. lower in air moving with a velocity of 660 feet per minute.

Influence of Convection Currents and Air Density upon Kata Formulas.—The kata formulas established by Hill (4, pp. 395 and 397), the inventor of the instrument, and Weiss (5, p. 17), for computing air velocity from the cooling powers of the kata, have been based on the assumption that for any given velocity the ratio of $\frac{H}{\theta}$ is a constant quantity. But Vernon (7, pp. 22 and 23) has already shown that this ratio is appreciably lower in air at 75°F. than in air at 50°F.

Our data confirm Vernon's claim over a much wider range of temperature. This is shown in Figure 3 where values of $\frac{H}{\theta}$ for three different tem-

[1] H = cooling power; F = kata factor = millicalories of heat lost by kata in cooling from 100° to 95° F.; T = cooling time in seconds; θ = (36.5−t) = temperature difference between mean kata temperature and air temperature in °C.

peratures, as computed from Figure 2, are plotted against the square root of velocity. It will be seen that for velocities exceeding 150 feet per minute

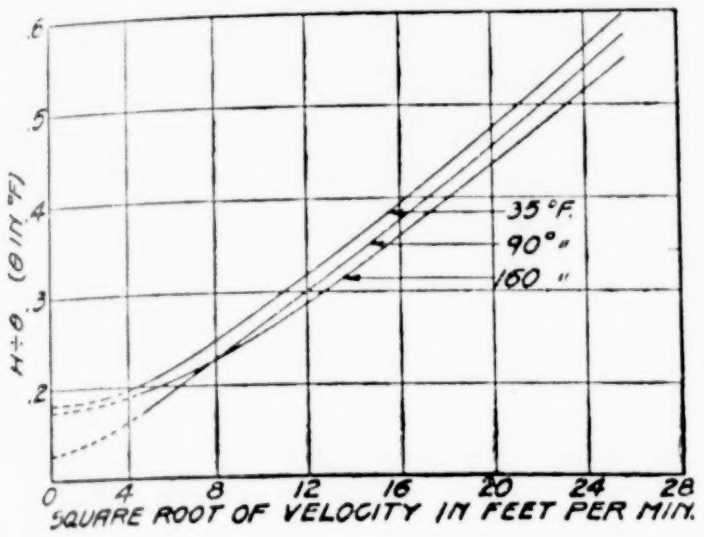

FIG. 3.—Influence of temperature on the relationship between $\frac{H}{\theta}$ and air velocity.

the ratio of $\frac{H}{\theta}$ decreases progressively as the temperature increases. We ascribe this variation to the decrease in the density of the air; whereas Vernon suggests in his experiments that varying humidity is the chief cause. Figure 3 also shows that for very low air velocities the $\frac{H}{\theta}$ values at 35° and 160°F. are considerably higher than those at 90°, probably on account of the natural convection currents already discussed. The small difference in the $\frac{H}{\theta}$ values at 35° and 160°F. is, apparently, purely a density effect since, θ being the same in both temperatures, the magnitude of the convection currents must be approximately the same. The currents differ, however, in direction—they rise in air at 35°F. and fall in air at 160°F.

This varying influence of convection currents led Hill (4, p. 397) to conclude that neither his recent equation nor Weiss' equation is applicable to low air velocities, because any straight line relationship between $\frac{H}{\theta}$ and square root of velocity which would hold for high air velocities would give too low values for velocities near 0 (see Fig. 3).

TABLE 1.—INFLUENCE OF HIGH DEW POINT TEMPERATURES UPON DRY KATA WARMING POWERS

AIR VELOCITY	TEMPERATURE		WARMING POWER	
	Dry Bulb	Dew Point	Observed	Average for Dew Points below 95°F.
ft./min.	°F.	°F.		
0	107.5	106.8	7.2	1.3
0	158.9	96.5	13.2	10.7
20	107.0	105.2	8.5	1.7
20	120.2	99.2	5.0	4.0
220	106.0	106.0	12.7	3.0
220	163.4	96.7	24.9	22.1
440	107.0	107.0	14.9	4.6
440	159.0	107.5	33.2	28.1

If the density factor is also to be taken into consideration, it would probably be a difficult task to derive kata equations which would not be too cumbersome for practical use.

Influence of Humidity, Dew Point, and Barometric Pressure.—A scrutiny of the deviations of the observed values of $\pm H$ in various humidities from the general trend in Figure 2 failed to disclose any definite humidity effect. This is entirely in accordance with previous experiences of Angus (8, p. 195) and Hill (4, p. 399).

Figure 2 does not include observations of warming powers in dew point temperatures exceeding 95°F., because

we found that the dry kata cannot be used under these conditions, on account of the condensation of moisture on the kata bulb. Warming powers

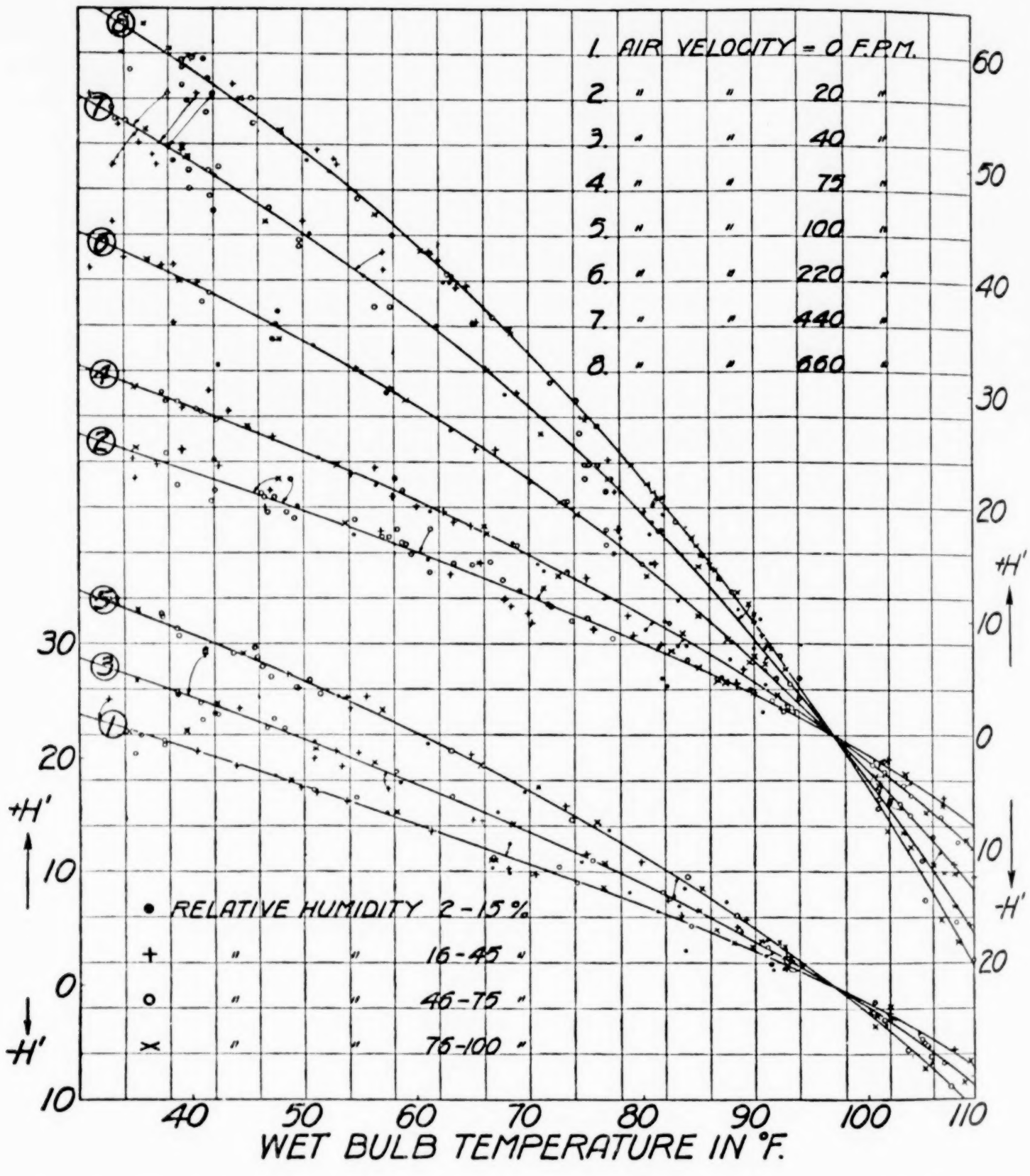

FIG. 4.—Wet kata cooling and warming powers (±H′) in relation to wet bulb temperature and air movement.

ably this is because, in addition to the sensible heat which it absorbs in warming from 95° to 100°F., the kata has to absorb the latent heat of the vapor

determined in such high dew points were considerably higher than those observed at the same dry bulb temperature and air velocity, with dew points below 95°F. (Table 1). Prob-

condensing on the bulb. In dry air with dew points between 95° and 100°F., part of the condensed vapor reevaporates as the kata warms from 95° to 100°, and the effect of con-

densation is counterbalanced to some extent (see Table 1). This limitation of the kata does not, however, detract from its practical usefulness, because such high dew points seldom occur in practice.

Changes in barometric pressure from 28.8 to 30.7 inches of mercury (732 to 780 mm. Hg), which were recorded in the course of our experiments, do not seem to affect the dry kata-thermometer measurably. For equally small pressure changes, computations by Hargood-Ash and Hill (2, p. 48) also show the effect to be negligible.

Wet Kata

Cooling and Warming Power in Relation to Wet Bulb Temperature and Air Movement.—Figure 4 confirms Hill's recent data (4, p. 402) by showing that, for any given air movement, the relationship between cooling power on the wet kata (+H′) and wet bulb temperature is not linear, as originally assumed in the equations of Hargood-Ash and Hill (2, p. 33).

The wet bulb temperatures in Figure 4 are those taken either by the sling or by the aspirating psychrometer. Readings taken by the wet bulb thermometer near the kata gave less satisfactory results. As in the case of the dry kata (Fig. 2), the wet kata curves in Figure 4 do not cross the wet bulb temperature axis at 97.7°F.; they converge at a temperature near or slightly below 97°F.

TABLE 2.—INFLUENCE OF HUMIDITY AND DRY BULB TEMPERATURE ON WET KATA READINGS

RELATIVE HUMIDITY	TEMPERATURE		AVERAGE DEVIATION OF OBSERVED VALUES OF ±H′ FROM GENERAL TREND (FIG. 4), AT AIR VELOCITIES OF		
	Wet Bulb	Dry Bulb	0–20 Ft./Min.	40–100 Ft./Min.	220–660 Ft./Min.
per cent.	°F.	°F.	*per cent.*	*per cent.*	*per cent.*
2–15	below 65	below 100	−0.4	−1.0	−0.2
	65–95	100–160	−16.4	−4.9	−0.5
76–100	below 65	below 70	+3.8	+0.8	+0.1
	65–95	70–100	+2.8	+3.2	−0.7
	100–110	100–115	−3.9	+10.1	+4.2

Influence of Humidity and Dry Bulb Temperature.—The curves in Figure 4 were drawn empirically through the averages of the observed values of ±H′, so as to represent the general trend regardless of relative humidity. It can be seen, however, that the trend of the low humidity points lies somewhat below the curves, and the trend of the high humidities slightly above. This is shown more clearly in Table 2, which gives the average percentage deviations of the observed values of ±H′ from the corresponding values on the curves, for our minimum and maximum humidity ranges. Small deviations are to be seen (Table 2) as long as the dry bulb temperature re-

mains below 100°F. When the temperature exceeds 100°F., however, the deviations appear to increase with temperature and decrease with air movement.

There are two pairs of influences at work which may explain these variations: (*a*) higher conductivity and specific heat of moist air as compared with dry air, and (*b*) reversed radiation and conduction effects on the wet kata in dry bulb temperatures exceeding 100°F.

The first two factors may explain the small negative deviations in dry air as contrasted with the positive deviations in moist air. The second two would probably account for the significant reduction in the cooling power in still and dry air at temperatures between 100° and 160°F., since under these conditions the heat gained by the kata through radiation and conduction partly offsets the heat lost by evaporation. Air movement tends to reduce the effects of both radiation and conduction (see Table 2) by accelerating evaporation from the surface of the water film on the kata bulb.

These tendencies are less noticeable in moist than in dry air, because in the former case the dry bulb temperature for any given wet bulb is much lower, and the amount of evaporation, or condensation, is too small to be appreciably affected by air movement.

The conclusion to be drawn is that both humidity and dry bulb temperature affect the wet kata to some extent, and that for practical purposes the effect is small and well within the experimental error. These effects became significant only in exceptionally hot and dry atmospheres, where the cooling power of the wet kata may, according to Table 2, be as much as 19 per cent. (= 16.4 + 2.8 per cent.) lower than that in moist air with the same wet bulb temperature range.

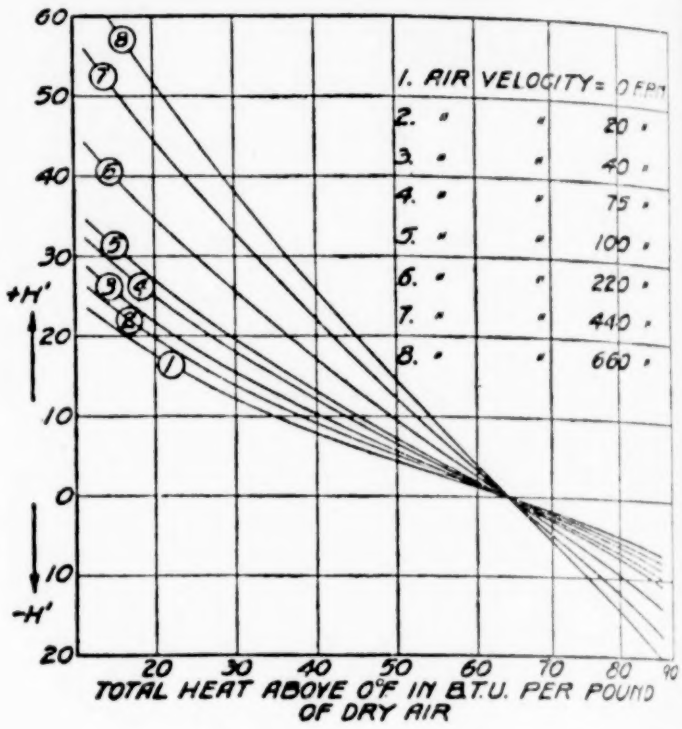

FIG. 5.—Wet kata cooling and warming powers (±H′), at various velocities, in relation to total heat content of air.

Cooling and Warming Power in Relation to Total Heat Content of Air.—Armspach and Ingels (9, p. 112) were the first to show an approximate linear relation between cooling power of the wet kata and total heat content of air, for wet bulb temperatures between 35° and 85°F. and for constant air velocities. Later, this relation was confirmed by Weiss (5, p. 26) and Hill (4, p. 404), although Hill (4, p. 406) does not consider it entirely satisfactory.

Figure 5 shows the relationship obtained in the present study over a wider range of wet bulb temperature. In this figure the cooling and warming powers (±H′) were taken from the curves of Figure 4, and the total heat values were obtained from Goodenough's tables (10, p. 430). It will be seen that the lines are not straight but

curve upward, probably for the same reasons as those discussed in connection with Figure 2.

In our opinion, a linear relationship between $\pm H'$ and total heat of air is not to be expected, because it would imply absence of convection currents in low temperatures and velocities as well as absence of any possible influence of air density at high temperatures and velocities. As a matter of fact, the presence of convection currents becomes very evident in temperatures below 40°F. from the clouds of water vapor which rise from the bulb of the wet kata.

Presumably, therefore, the concave curvature in Figure 5 would explain the failure of Hill's (4, p. 403) assumed straight lines to cross the total heat axis at a value corresponding to his mid-cooling point of 97.7°F. They converge, instead, at a value corresponding to 95°F.

Computation of Air Velocity from Kata Readings

For reasons already discussed, we were unable to derive formulas which would hold, even approximately, over the range of air conditions used in this study. We therefore present the final results in the form of charts from which the air velocity can be computed. These charts are applicable to horizontal air currents striking the kata bulb at right angles. For any other direction, errors would be introduced, and in descending air currents the results would be unreliable, as Vernon (7, p. 28) has shown.

The standard kata is inaccurate also when used as an anemometer in air temperatures between 85° and 110°F., because these temperatures are near its cooling range and therefore air movement has little effect (see Figs. 2 and 4).

Velocity Chart for Dry Kata

The chart in Figure 6 was constructed from graphs similar to those in Figure 2 drawn on large cross-section sheets. In order to determine the velocity, follow the curve corresponding to the given dry bulb temperature to the right until it meets the given value of $\pm H$, and read off the velocity vertically on the horizontal scale.

Compared with previous calibrations, our results, as given in Figure 6, are in very close agreement with Vernon's (7, p. 25) for velocities up to 175 feet per minute, and within the temperature range of 50° to 75°F. covered by Vernon's experiments. For velocities exceeding 175 feet per minute, the results overlap Vernon's (7, p. 23), Hill's (4, p. 396), and Weiss' (5, equation p. 17) to some extent. They are somewhat higher than Hill's and Weiss' for temperatures below 50°F. and somewhat lower for temperatures between 70° and 90°F., for reasons already discussed. For temperatures exceeding 100°F. there are no previous data to compare with our results.

The chart in Figure 6 cannot be used when the dew point temperature exceeds 95°F.

Velocity Chart for Wet Kata

The wet kata velocity chart in Figure 7 was constructed from Figure 4, and it is to be used in the same manner as the dry kata chart. Velocities computed from wet kata readings are,

however, less accurate than those computed from the dry kata readings, for several reasons. In the first place, the wet kata, even under ordinary room conditions, cools too fast (in about twenty-five seconds) to be timed accurately. In more extreme conditions, such as 30° to 50°F. wet bulb and velocities exceeding 400 feet per minute, the wet kata cools so fast (in

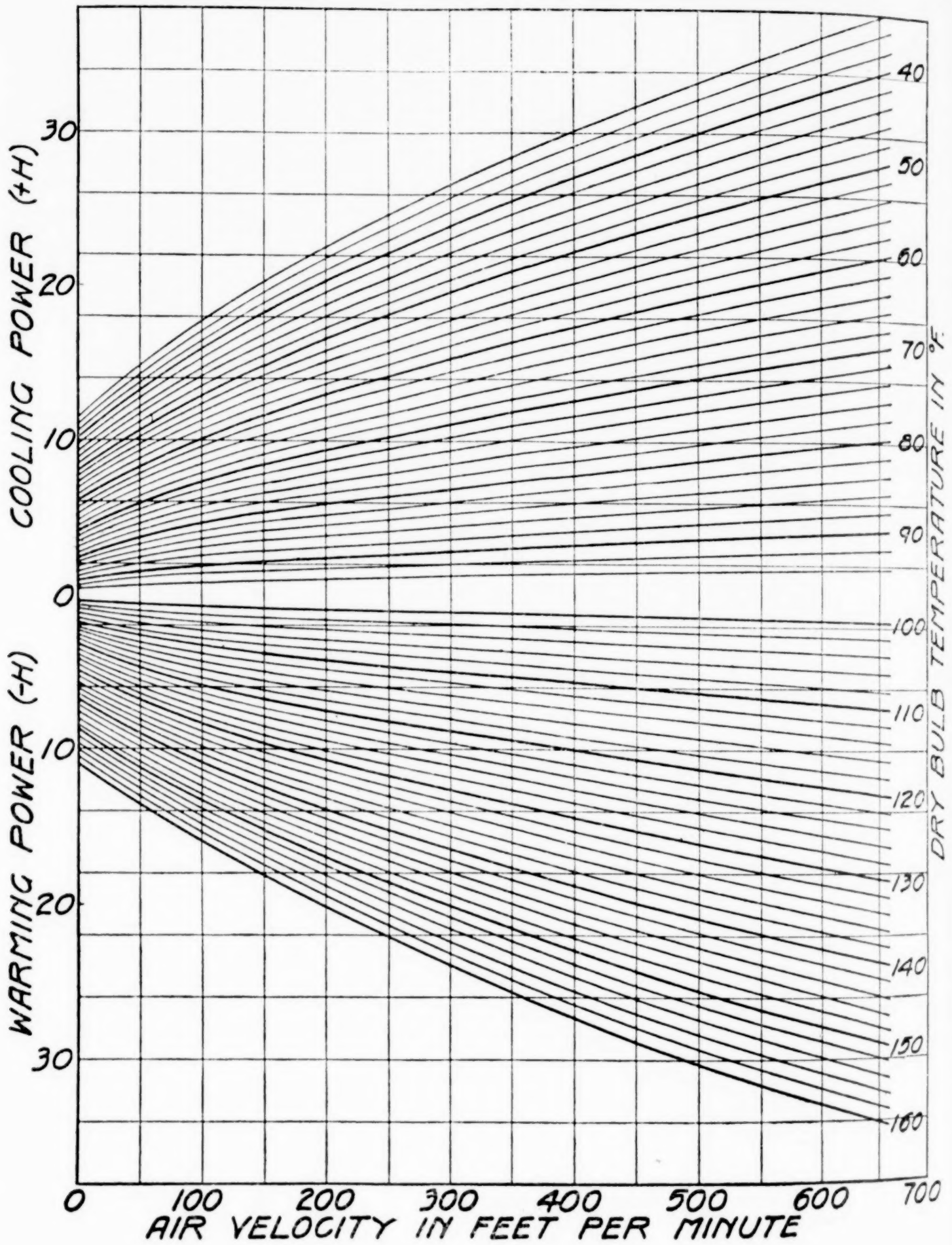

FIG. 6.—Dry kata chart for computing air velocity.

less than ten seconds) that its readings are quite unreliable (see Fig. 4).

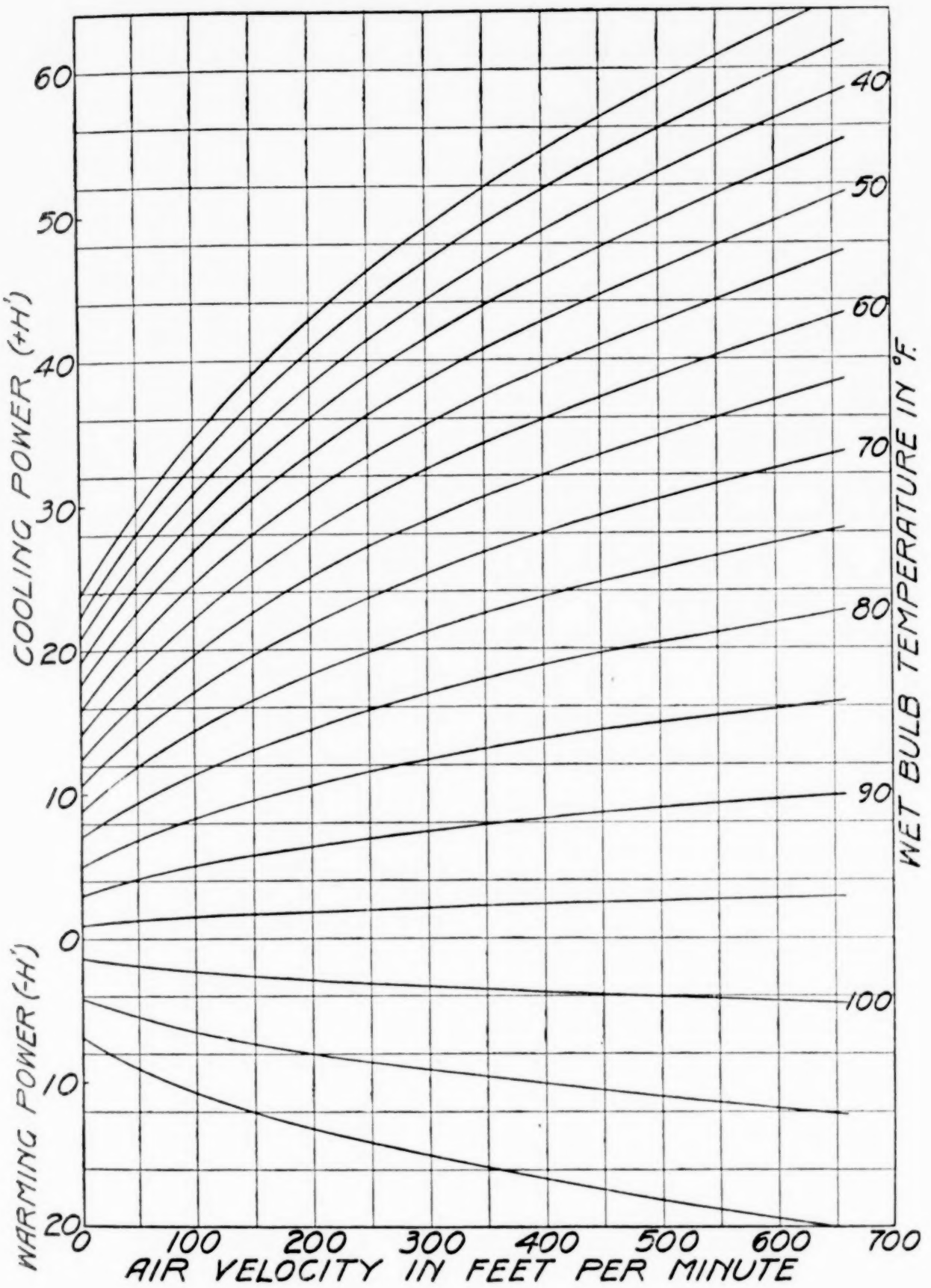

FIG. 7.—Wet kata chart for approximate computation of air velocity.

Moreover, errors may be introduced from the use of different wicks and also from failure to obtain the true psychrometric wet bulb temperature.

These errors would, presumably, explain at least in part the inconsistencies in all wet kata calibrations. Our results, as a general rule, fall in between the values obtained by Hill (4, p. 401) and those of Weiss (5, equation p. 25) but they are nearer to Hill's than to Weiss'. Except in very low temperatures and velocities, Weiss' results are the highest of the three.

Summary

The kata-thermometer has been calibrated for air velocities from 0 to 660 feet per minute, for dry bulb temperatures from 35° to 165°F., and for wet bulb temperatures from 32° to 112°F.

The dry kata is affected by dry bulb temperature and air movement, but for any given air velocity its cooling or its warming rate is not a straight line function of temperature, owing to (*a*) varying influence of natural convection currents and (*b*) varying effect of air density. Humidity has little or no effect on the dry kata so long as the dew point remains below 95°F. When the dew point exceeds 95°F. the dry kata cannot be used as an anemometer because water vapor condenses on its bulb. The usual changes in barometric pressure have no appreciable effect on the dry kata.

The wet kata is chiefly affected by wet bulb temperature and air movement. To some extent it is also affected by humidity and dry bulb temperature, particularly in very hot and dry atmospheres. The relationship between wet kata cooling or warming power and total heat content of air is not linear, as heretofore assumed; an equation of a higher order would therefore be necessary to express the relation.

Owing to varying effects of convection currents and air density, it is very difficult to derive equations which would fit the experimental data accurately over a fairly wide range of air conditions.

For practical use, charts are given by means of which the air velocity can be computed from kata readings for any air condition within the experimental range.

BIBLIOGRAPHY

1. Drinker, P.: Laboratories of Ventilation and Illumination, Harvard School of Public Health, Boston. This Jour., 1924, *6*, 57.
2. Hargood-Ash, D., and Hill, L.: The Kata-Thermometer as a Physical Instrument. Med. Res. Council, Special Rep. Series No. 73, p. 14. London, H. M. Stationery Office, 1923.
3. The Wahlen Gage (Illinois Micromanometer). Reprinted from Bull. No. 120, Engineering Experiment Station, Urbana, Ill., March, 1921.
4. Hill, L., Angus, T. C., and Newbold, E. M.: Further Experimental Observations to Determine the Relations between Kata Cooling Powers and Atmospheric Conditions. This Jour., 1928, *10*, 391.
5. Weiss, P.: Die hygienischen Grundlagen der Lüftungstechnik mit spezieller Berücksichtigung der Kata-Thermometrie zur Bestimmung der Entwärmungsverhältnisse. Arch. f. Hyg., 1926, *96*, 1.
6. Angus, T. C.: The Determination of the Factor of the Kata-Thermometer. This Jour., 1924, *6*, 20.
7. Vernon, H. M.: The Calibration of the Kata-Thermometer. Med. Res. Council, Special Rep. Series No. 100, p. 19. London, H. M. Stationery Office, 1926.
8. Angus, T. C.: The Effect of Moisture upon the Cooling Power of Air as Measured by the Dry Bulb Kata-Thermometer. *Ibid.*, No. 73, 1923, p. 195.

9. Armspach, O. W., and Ingels, M.: Temperature, Humidity and Air Motion Effects in Ventilation. Tr. Am. Soc. Heating and Ventil. Eng., 1922, *28*, 103.

10. Harding, L. A., and Willard, A. C.: Mechanical Equipment of Buildings. Vol. 1. Heating and Ventilation. New York, John Wiley & Sons, Inc., 1916.

BOOK REVIEW

An Introduction to Biophysics. By *David Burns*, M.A., D.Sc., Professor of Physiology in the University of Durham; Late Grieve Lecturer on Physiological Chemistry in the University of Glasgow. With a Foreword by Prof. D. Noël Paton, M.D., LL.D., F.R.S., etc. Second edition. Cloth. Pp. xix, 580 with illustrations and indexes. New York: The Macmillan Co., 1929.

An explanation of the phenomena of life is a goal toward which physiologists have long converged and it goes without saying that, without the ever-increasing light of physics and chemistry to illumine their way, their progress would have been slow indeed. As the application of physics and chemistry is extended to physiology it is more and more apparent that a great number of the characteristic reactions of living matter can be explained in terms of ordinary physical processes. The extent to which these physical and physicochemical laws have been applied to the actions of living things is strikingly exemplified in David Burns' "Introduction to Biophysics."

This is a book which not only condenses information of direct interest to the physiologist, but is also delightfully informative to the general reader. One cannot fail to be interested in the length of time mules could live in the Hudson tunnel during its construction, or in the amount of work done by an orator in making a speech—especially when the latter is a Frenchman and speaking in a large reverberating hall.

In substance the book consists of five sections in Part I and covers the field of biophysics very adequately. *Section I*, "Energetics," includes chapters on the laws of energy, the storage of energy, calorimetry, the animal as a machine, the energy of substance in solution, and surface energy. Under "Cellular Mechanics" in *Section II* discussion is centered in ionization, colloids, soaps and emulsions, enzymes, membranes, the cell, and radioactivity. The eight chapters of *Section III*, "Cell Communities," describe in turn: The Army Wherewith the Body Wages War with Nature—The Muscle Cells, Manufacturing Cells, The Army for Home Defence, The Civil Engineers of the Body; The Intelligence Service—Nerve Cells, Outposts of the Intelligence Service, (*a*) General and Intra-Communal Receptors; (*b*) Distance Receptor for Sound. The Ear; and (*c*) Distance Receptor for Light. The Eye. *Section IV* relates to "Transport:" Inland Transport—The Blood, The Respiratory Function of the Blood, Loading Up, The Circulation, The Electrocardiogram; Overseas Transport—External Respiration, The Voice, Alimentary Canal; and Movements of the Limbs. *Section V* comprises a discussion of the animal as a whole—the preservation of neutrality, the regulation of temperature, tropisms, adaptation, growth, development, death and dissolution, and the efficiency of the organism.

A valuable part of the book (Part II) consists of what might be termed a laboratory manual of biophysics with experiments illustrating phenomena discussed in the preceding sections. The experiments are described in detail and offer much of interest either for lecture demonstration or for laboratory study.

The author deserves the thanks of all who are interested in the mechanism of living matter for presenting such a wealth of material in so agreeable a form.—*L. T. Fairhall.*

BOOKS RECEIVED

Books received are acknowledged in this column and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers and as space permits.

CRITERIA FOR THE CLASSIFICATION AND DIAGNOSIS OF HEART DISEASE. By a Committee: Joseph H. Bainton, M.D., Robert L. Levy, M.D., W. C. Munly, M.D., M.C., U.S.A., Harold E. B. Pardee, M.D., Chairman, appointed by the Heart Committee of the New York Tuberculosis and Health Association, Inc. Arranged in conformity with the nomenclature for cardiac diagnosis approved by the American Heart Association. Cloth. Pp. xi, 92. New York: Paul B. Hoeber, Inc., 1928.

PRESCRIBING OCCUPATIONAL THERAPY. By *William Rush Dunton, Jr.* Cloth. Pp. 143 with index. Springfield, Ill., and Baltimore, Md.: Charles C. Thomas, 1928.

TEACHING HEALTH IN FARGO. By *Maud A. Brown.* Cloth. Pp. xiv, 142. New York: The Commonwealth Fund, Division of Publications, 1929.

A WATER PROGRAM FOR CAMPS, FOR CAMP WATERFRONT LEADERS AND CAMP DIRECTORS. By *Thomas K. Cureton, Jr.*, Director of Physical Education, Suffield School, Suffield, Conn.; Life Saving Field Representative of the American National Red Cross. Published for the American National Red Cross. Paper. Pp. 162. Philadelphia: P. Blakiston's Son & Co., 1929.

THE CONQUEST OF CANCER BY RADIUM AND OTHER METHODS. By *Daniel Thomas Quigley*, M.D., F.A.C.S., Instructor in Surgery in the University of Nebraska College of Medicine; Fellow of the American Medical Association; Member of the American Association for the Advancement of Science, Nebraska Academy of Sciences, North American Radiological Society, American Radium Society; Fellow of the American College of Radiology, etc.; Director of the Radium Hospital of Omaha. Cloth. Pp. xix, 539 with illustrations, appendix, and index. Philadelphia: F. A. Davis Co., 1929.

THE CLINICAL ASPECTS OF VENOUS PRESSURE. By *J. A. E. Eyster*, B.Sc., M.D., Professor of Physiology, University of Wisconsin; Associate Physician, Wisconsin General Hospital, Madison, Wis. Cloth. Pp. x, 135 with bibliography. New York: The Macmillan Co., 1929.